U.S. Army Research Laboratory

SUMMER RESEARCH TECHNICAL REPORT

Target Modeling for Ground Mobile Branch (GMB)

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14. ABSTRACT
This report documents my efforts and the insights I have gained while serving as a target modeler for the Ground Mobile Branch (GMB) of the Survivability Lethality Analysis Directorate (SLAD). In support of the Branch?s role of providing modeling and simulation support through the ballistic analysis of current and future vehicular systems, my primary task was to gain knowledge and insight into the analysis process through understanding the role SLAD plays in the development of combat systems, specifically, how SLAD?s analysis results leverage vehicle evaluation and assessment in order to lead to modifications, which will ultimately increase the survivability of a particular system. To achieve this, I participated in vehicle measurements using metrology equipment (using three-dimensional [3-D] BRL computer aided design (CAD) target geometries and the MUVES vulnerability model), supported target geometry development through the production of component parts, and observed various test-shots intended to produce data for use in MUVES analysis.

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Abstract

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Student Bio

I am currently an undergraduate student at the University of Maryland, Baltimore County (UMBC) majoring as a mechanical engineer in my junior year of study. I served as a target modeler for the Ground Mobile Branch (GMB) in the previous summer of 2010 as a Student Temporary Employment Program (STEP) hire and was invited to return to further my developing computer-aid design (CAD) skills and deepen my understanding of the interconnectivity of the Branches in their ultimate mission. My future goal is to transfer to Weapons Materials Research Directorate (WMRD) in order to aid in the study and design of current and future armor systems and their component materials.

1. Introduction

The Ground Mobile Branch (GMB) contributes to the U.S. Army Research Laboratory's (ARL) mission by modeling and analyzing ground-based vehicular systems. This is typically achieved through the use of high-fidelity computer-aided design (CAD) models and use of the MUVES-S2 (referred to as MUVES) analysis software. The results generated from the analyses of ground-vehicle systems are used to make vehicle assessment recommendations for modifications aimed at achieving vulnerability reductions.

Due to the nature of our mission, a large percentage of our efforts are involved in producing the data and models necessary to support the MUVES software. MUVES is a suite of programs designed to aid in the prediction of vehicle vulnerability by incorporating vehicle models, penetration algorithms, and a wide variety of other data relating to performance of both the threat and target (*1*). These inputs are required before MUVES is capable of running a quality analysis and developing them is a primary task for any analysis.

An ongoing project GMB is currently involved in is the development of a target vulnerability model of the Special Operations Command (SOCOM) variant of the Mine Resistant Ambush Protected (MRAP) All Terrain Vehicle (MATV). I have participated directly in this project through my work in applying modern data collection techniques using metrology equipment and my contributions relating to creating vehicle target geometries. In addition to this, I have observed the testing process used to develop behind armor debris (BAD) models for the MUVES software.

2. Description of Effort

2.1 Data Collection Through Metrology

The development of a target description begins with the identification of its intended use. Radar signature analyses require highly accurate surface representations compared to a standard vulnerability analysis, which requires accurate CAD geometries of all components and internal systems. These requirements shape the data collection process: accurate surfaces can be derived from extremely dense point cloud data, whereas relative positions and basic geometries can be obtained through three-dimensional (3-D) scanning technologies and hand measurements. Traditionally, the requirements of GMB require the constraints of the latter.

For the SOCOM MATV modeling project, our collectors used several coordinate measuring machines (CMMs) to ease and shorten the collection process. One CMM (figure 1) uses two rotating laser emitters to identify the location of the CMM and maintain a constant global

coordinate system as data are collected. This system is known as an Indoor Global Positioning System (iGPS) and is used for the capture of reference points over the vehicle. The second CMM used by our collectors is known as a scanning arm (figure 2). Data are collected through an interchangeable tip at the head of the arm; a small sharp tip is used for collecting point data and a small ball-head tip is used for capturing curves, lines, and edges.

Figure 1. iGPS unit used by TMT to capture reference points. Points are collected through the tip of the arm shown at the top.

Figure 2. Scanning arm used to collect point data and capture curves.

Proper data collection techniques outline a general procedure for collecting basic geometries and reference points. The process begins with the staging of the vehicle; this is a blanket term that includes aligning articulation points and setting the vehicle into a typical combat configuration, as well as any other preparation that must be done on either the vehicle or the workspace environment. After staging the vehicle, reference points are identified on the vehicle. Reference points allow collectors to overcome the range limitations of their metrology equipment by providing common points between multiple data sets (when moving the positioning equipment,

small discrepancies in the global coordinate system may arise due to the sensitive nature of these devices), which serve as references for fitting all data sets to one common coordinate system (*2*). These points may be either predetermined standards or simply symmetry points that will aid in aligning the future target model's data points. Once the reference points have been identified, the actual collection of data can begin. Data are collected in the form of isolated points from surfaces and captured edges. Complex shapes are broken down such that only the edges and points necessary to rebuild them within a CAD package are taken.

2.2 Modeling

GMB places a large emphasis on the development of high-fidelity CAD to ensure the geometries used for analysis in MUVES do not introduce unnecessary error through the improper representation of targets. A wide variety of CAD packages (including but not limited to Pro-E/Creo, Spaceclaim, and Rhino) are used to develop the necessary geometry depending on the situation and personal preference of the modeler in question. All models must eventually be converted into a BRL-CAD™ format as it is the only CAD package currently supported by MUVES, making it critical to the operations of GMB.

The final product of the data collection process provides a foundation for a developing CAD model. Parts and component level structures are built through the isolation (figure 3) and conditioning of captured data; a process that entails normalizing and projecting captured curves and points to planar regions. To accomplish this, modelers use analysis tools within the CAD packages to determine critical values for the data in question (circle radii, line segment lengths, etc.) and rebuild the curves according to both ideal and measured values. This accounts for error in the collection stage and eases the final step of aligning every component within a master file. Conditioned data and geometric relations are then used to create the solids and surfaces necessary to build up the component parts.

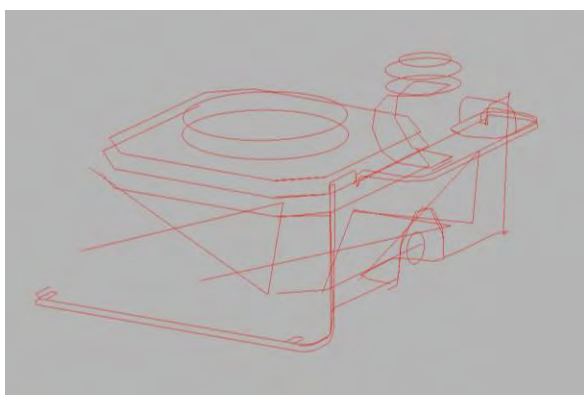

Figure 3. Basic geometry that has been isolated for use in constructing a representative model.

The SOCOM MATV modeling process saw the simultaneous development of two distinct models within both Rhino, a CAD package based on non-uniform rational B-splines (NURBS),

and BRL-CAD™ format. This dual-package development allowed for rapid development of components within Rhino and the subsequent importing of these parts into BRL-CAD™ to be used as references for rebuilding them natively. Rebuilding parts in BRL-CAD™ that have been imported from Rhino is preferred to the actual conversion of components as it aids in minimizing the amount of error introduced when the conversion process approximates surfaces. My contributions to the modeling project are the addition of completed components for the Rhino model (figure 4), including various antenna and their mounts, stretcher brackets, and assorted detail work among other components.

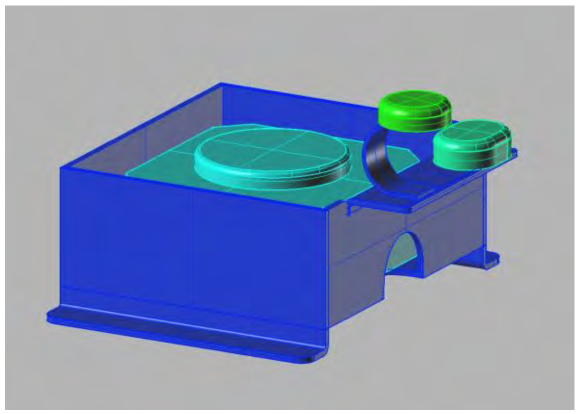

Figure 4. A completed model of a global positioning system (GPS) unit and its casing. The model is derived from conditioned basic geometry.

2.3 Test Shot Data

Just as the accuracy of target geometry can be a limiting factor in a MUVES analysis, the characteristics and material properties of both the threat and target need to be accurate in order to ensure the software operates as accurately as possible. Other complications that affect vehicle survivability, such as behind armor debris (BAD) and other secondary effects, must be considered through the development of suitable simulation inputs.

Coupon test data provide the input that defines both the threat characteristics and the performance and material properties of the armor being fired upon. Threats are reduced through this experimentation to a series of tables and values for properties including impact velocity, fragment mass, and relative penetrative power. The strength of vehicle armor is typically approximated by an experimentally determined equivalence to a given thickness of rolled homogeneous armor (RHA). Tests that calculate these values and approximations are typically conducted by the Weapons Materials Research Directorate (WMRD). These values are input into MUVES as part of a series of penetration algorithms.

BAD, also known as spall, can be a significant concern in determining vehicle survivability. In order to model more effectively and better predict its impact on crew and internal components,

testing is routinely performed by the Survivability Lethality Analysis Directorate (SLAD) to investigate and develop new characterizations of spall proliferation. Current test methods involve firing a penetrator at a coupon (figure 5) to develop spall fragments that impact and penetrate a series of witness packs (figure 6). The path and depth of the channels the spall fragments generate allow for approximations of fragment mass/velocity and fragment trajectory (*3*). These data allow the development of an approximated "spall cone" model for use within MUVES analysis.

Figure 5. Snapshot of a BAD test prior to munition detonation. The penetrator is not displayed.

Figure 6. Witness plate after being hit with spall generated from the testing process.

3. Results and Discussion

Every aspect of my modeling experience and the analysis process is more than a self-contained unit—each part acts as a link in a chain, passing on information and products that are used by the

next step. Metrology provides the foundation for the development of target geometries through the accurate and efficient acquisition of basic shapes and data. Testing data produce properties and relations that are used to model threat and armor performance on an analytical level. Both products are then integrated into the analysis directly through the use of the MUVES software. The results and revelations these analyses yield represent the next step of the chain and are the final product that SLAD produces.

Because every aspect of the process has some influence on the final result, it becomes clear that every input at every stage is important. Work in any one link cannot falter or produce sub-par products as it leads to inefficiencies and inaccuracies in all following links. This concept of interconnectivity helped clarify the concept that my work and its quality directly correlate to my utility. For every measurement I err in accuracy or any target description I incorrectly develop, I have produced a flawed product that will, in turn, lead to a less accurate assessment of vehicle survivability. The idea that my errors could result in excess effort to rectify my mistakes within later links of the chain provides enough initiative to ensure I produce the highest caliber of work that I am capable of.

The ultimate link in our design chain is the Soldier—to ensure they can operate effectively and with success, we must be certain that every link in our chain is secure.

4. Summary and Conclusions

This paper documents my experiences and understanding of the analysis process while serving as a target modeler for GMB. In my course of duty, I have performed work in areas including the data gathering processes and the development of target geometries. Additionally, I have attended coupon testing and gained an understanding of the subsequent analysis of the results.

Through training and practical application of skills, I have furthered my proficiency in multiple CAD packages; developed a sense for the techniques and methodology used within modern metrology; and gained an understanding of the procedures and standards used for armor characterization.

In gaining an understanding of both the direct impact of my work and the consequences it will have on those who rely on it, my own appreciation of the interconnectivity of the work both GMB and SLAD as a whole perform within the structure of ARL has deepened. Each Branch supports the whole in our ultimate mission—the betterment of the Soldier.

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